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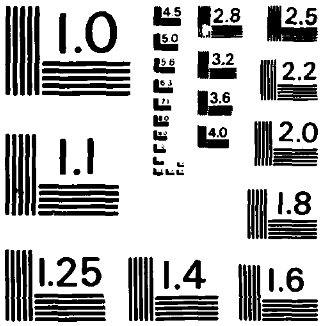

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IDA RECORD DOCUMENT D-26

R&M PROGRAM REVIEW ELEMENTS DOCUMENT
(IDA/OSD R&M Study)

Paul F. Goree
IDA R&M Case Study Director

Thomas A. Musson
Evaluation Research Corp.

August 1983

The views expressed within this document are those of the working group only. Publication of this document does not indicate endorsement by IDA, its staff, or its sponsoring agencies.

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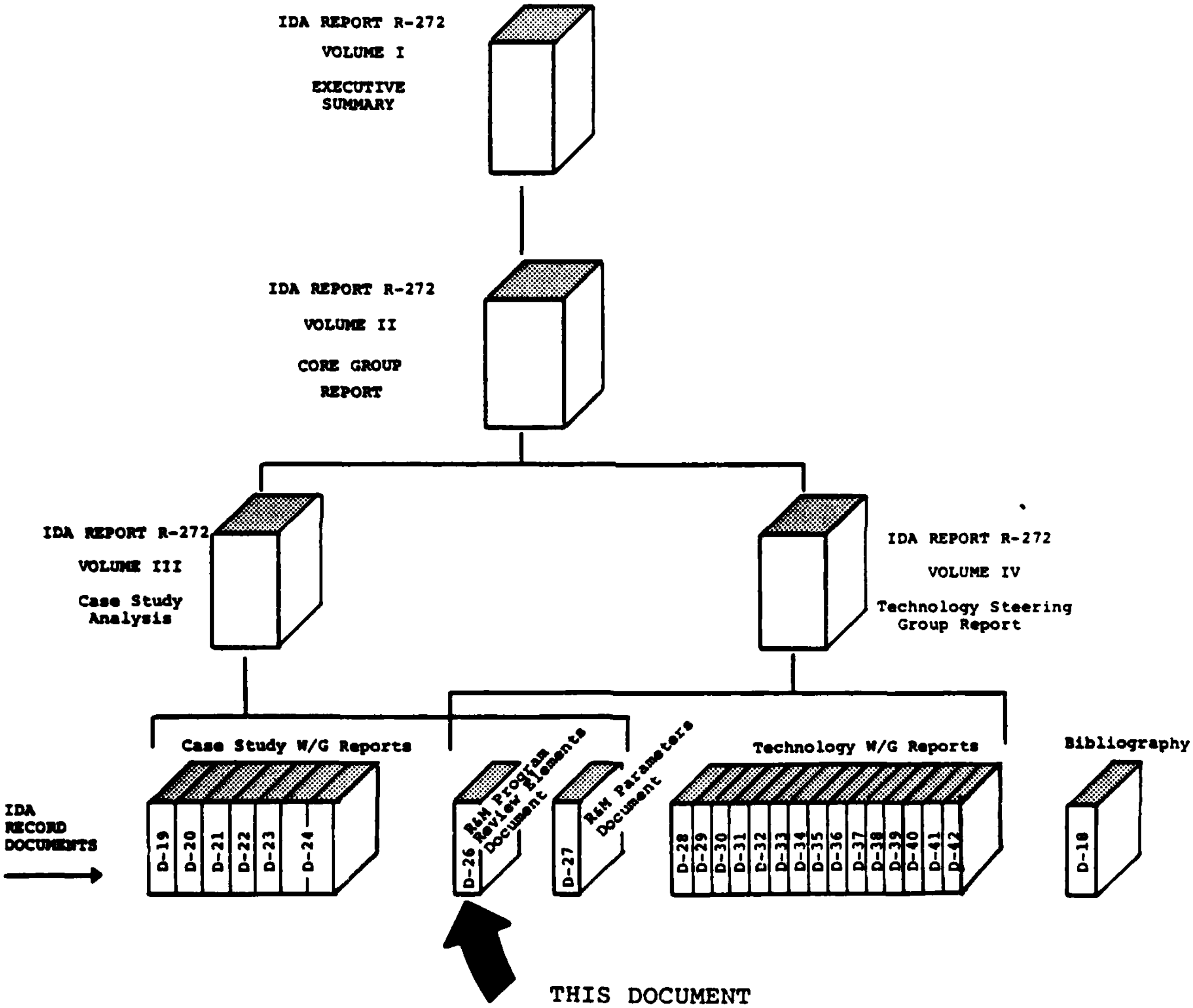
Contract MDA 903 79 C 0018
Task T-2-126

RELIABILITY AND MAINTAINABILITY STUDY

— REPORT STRUCTURE —



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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This document describes in detail how weapon systems development programs should be structured for reliability and maintainability. Not only are the key elements identified but they are defined, and key questions relative to those elements are addressed.

PREFACE

As a result of the 1981 Defense Science Board Summer Study on Operational Readiness, Task Order T-2-126 was generated to look at potential steps toward improving the Materiel Readiness Posture of DoD (short title: R&M Study). This task order was structured to address the improvement of R&M and readiness through innovative program structuring and applications of new and advancing technology. Volume I summarizes the total study activity. Volume II integrates analysis relative to Volume III, program structuring aspects, and Volume IV, new and advancing technology aspects.

The objective of this study as defined by the task order is:

> "To identify and provide support for high payoff actions which the DoD can take to improve the military system design, development and support process so as to provide quantum improvement in R&M and readiness through innovative uses of advancing technology and program structure."

The scope of this study as defined by the task order is:

> To (1) identify high-payoff areas where the DoD could improve current system design, development program structure and system support policies, with the objective of enhancing peacetime availability of major weapons systems and the potential to make a rapid transition to high wartime activity rates, to sustain such rates and to do so with the most economical use of scarce resources possible, (2) assess the impact of advancing technology on the recommended approaches and guidelines, and (3) evaluate the potential and recommend strategies that might result in quantum increases in R&M through innovative uses of advancing technology.

The approach taken for the study was focused on producing meaningful implementable recommendations substantiated by quantitative data with implementation plans and vehicles to be provided where practical. To accomplish this, emphasis was placed upon the elucidation and integration of the expert knowledge and experience of engineers, developers, managers, testers and users involved with the complete acquisition cycle of weapons systems programs, as well as upon supporting analysis. A search was conducted through major industrial companies, a director was selected, and the following general plan was adopted.

GENERAL STUDY PLAN

Vol. III	•	Select, analyze and review existing successful program
Vol. IV	•	Analyze and review related new and advanced technology
Vol. II	(•	Analyze and integrate review results
	(•	Develop, coordinate and refine new concepts
Vol. I	•	Present new concepts to DoD with implementation plan and recommendations for application.

The approach to implementing the plan was based on an executive council core group for organization, analysis, integration and continuity; making extensive use of working groups, heavy military and industry involvement and participation, and coordination and refinement through joint industry/service analysis and review. Overall study organization is shown in Fig. P-1.

The basic case study approach was to build a foundation for analysis and to analyze the front-end process of program structuring for ways to attain R&M, mature it, and improve it.

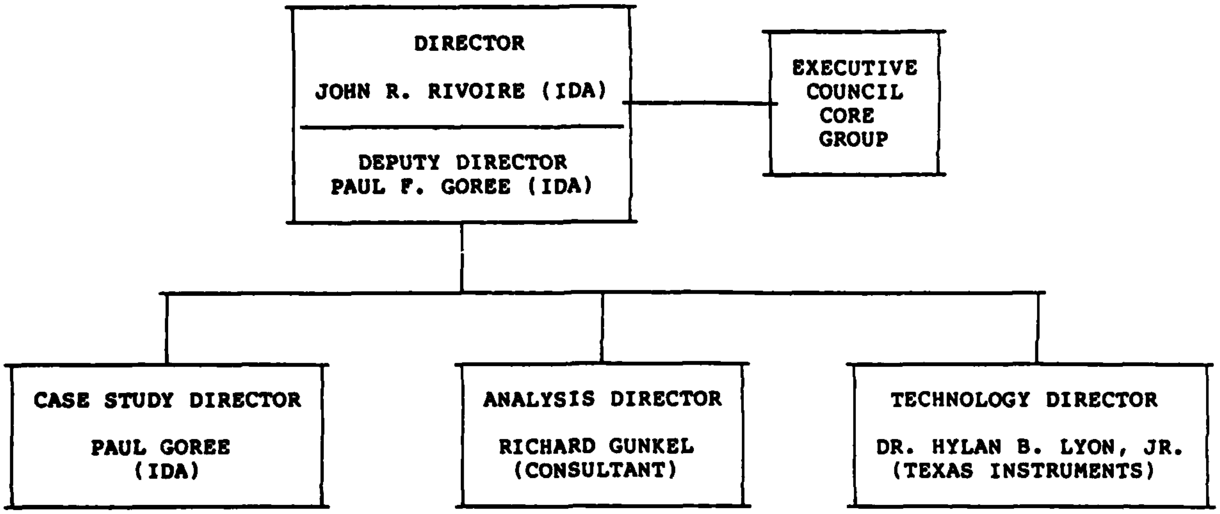

FIGURE P-1. Study organization

Concurrency and resource implications were considered. Tools to be used to accomplish this were existing case study reports, new case studies conducted specifically to document quantitative data for cross-program analysis, and documents, presentations, and other available literature.

This document records the R&M program review elements which were used as guidelines for the case study activities. The views expressed within this document are those of the working group only. Publication of this document does not indicate endorsement by IDA, its staff, or its sponsoring agencies.

R&M PROGRAM REVIEW ELEMENTS

DOCUMENT

TASK ORDER NO.

MDA 903 79 C 0018: T-2-126

INSTITUTE FOR DEFENSE ANALYSES
SCIENCE AND TECHNOLOGY DIVISION
1801 N. BEAUREGARD STREET
ALEXANDRIA, VA 22311

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R&M PROGRAM REVIEW ELEMENTS

CONTENTS

CONTRACT

ELEMENT: R&M Requirements

DEFINITION: This element addresses the question of whether the reliability (maintainability or diagnostic) requirements are included in the contract as contractual requirements or as goals.

SCOPE: This element will address reliability, maintainability and testability. It will address both quantitative requirements and qualitative requirements.

QUESTIONS TO BE ADDRESSED: Were there quantitative and qualitative R&M requirements? Are they stated clearly? Is their growth to a mature, or field value specified? Were requirements sufficiently detailed and were verifications also required? How do these compare to similar systems? List the requirements together with assessment of difficulty in attaining.

DISCUSSION: A number of years ago, R&M programs routinely included quantitative R&M goals. This approach placed R&M at a disadvantage versus other technical requirements on the system which were specified as contract requirements. Today most programs include quantitative R&M requirements if they are appropriate for the item being developed. To properly compete for contractor attention and resources, the R&M numerics should be specified in the contract (specification or statement of work) as contract requirements as opposed to goals. Qualitative

areas may also be specified as requirements. All contract requirements must have a contractually specified verification to be truly enforceable requirements. There are several measures of R&M which qualify the numeric value, and must be taken into consideration, such as inherent, induced, no defect, field removal rates, etc. These can drive design decisions and must be distinguished from each other in documenting the requirements. The planned R&M growth, if any, must also be considered (see Test and Evaluation).

CONTRACT

ELEMENT: Mission Profile Establishment

DEFINITION: The mission profile is a time-phased description of the events and environments an item experiences from initiation to completion of a specified mission, to include the criteria of mission success or critical failures.

SCOPE: This element should address the development of the mission profile for the system or a number of mission profiles for multi-mission systems. The profile(s) shall define, as a minimum, the boundaries of the performance envelope and provide the timeline (environmental conditions and applied/induced stresses versus time) typical of operations within that envelope (e.g., engine throttle cycles).

QUESTIONS TO BE ADDRESSED: Was a mission profile (or profiles) defined prior to full scale development or earlier? Did the profile address in adequate detail the time phasing of operation, maintenance, the predicated environmental conditions, and the rate of change of system conditions? Were these mission profile conditions and operations used as inputs to the stress and design analyses? To what level of system partitioning was the profile apportioned? Did the system design criteria, worst case analysis, derating criteria BIT/FIT compensate for the conditions identified in the mission profile? Was the defined mission profile evaluated during early system testing and operation to determine if it was still valid? Were there changes

to the profile? When? How were these identified to the contractor?

DISCUSSION: Prior to the beginning of detailed design, a mission profile (or profiles) should be defined to indicate the system utilization, maintenance concept, time phase sequence of system operation, and time phase sequence and period of environmental conditions. This profile must be based on the best available data, but it must be recognized that predicting system usage and environments is not an exact science. As the system is developed, additional effort must be expended to determine if these projections have proved to be incorrect.

CONTRACT

ELEMENT: Life Profile Establishment

DEFINITION: The life profile is a time-phased description of the events and environments an item experiences from manufacture to final expenditure or removal from the operational inventory, to include one or more mission profiles.

SCOPE: This element addresses the entire life profile, with the exception of the details of the mission profile(s) which are addressed in the mission profile element.

QUESTIONS TO BE ADDRESSED: Has the life profile (production through disposal) been established? Does the system have periods of non-mission time that are significant to the development because of their relative duration (e.g., missiles with long storage periods) or unusual environments (e.g., electronics stored in an uncontrolled environment)? What is the basis for estimates of the environment to be expected in these non-mission phases? Does this profile address the impact of humans on the system in the phases of the life profile? How did the life profile impact on the detailed design requirements? Were specific design or support alternatives considered? Did the program validate the environments of the life profile through the test program or in-service assessments?

112/6-1

DISCUSSION: During the development of system requirements it is essential to develop a definition of the system's life profile. This is particularly true if some of the unique aspects of the non-mission portions of the life profile need to be translated into design requirements. The definition of the life profile needs to address operational and support phases that may not be accurately defined by the system contractor. It is a question of identifying what is actually done in operational service versus information contained in planning documents. There is also a potential problem in that new systems may cause user personnel to change their method of operation and to cause a significant change in the life profile without adequate evaluation of the technical impact.

CONTRACT

ELEMENT: R&M Failure Definition

DEFINITION: This element is the definition of failure, malfunction, maintenance, etc., that provide meaning to other elements such as requirements and testing.

SCOPE: This element addresses not only the definition of failures, but also other definitions that pertain to R&M activities including maintenance, man hours, diagnostic detections, no defect removal rates, downtime, etc.

QUESTIONS TO BE ADDRESSED: Was the definition of failure established prior to design and in concert with the R&M requirements? Was there an operational definition in addition to a contract definition? Was the definition adequate to prevent conflict during testing and adequate to result in R&M results that were meaningful? Were the maintainability and diagnostic requirements adequately supported by definitions?

DISCUSSION: The R&M requirements must be established in a defined context. This definition of failure, manhours, maintenance, operating time, critical failures, etc., must be completed before the quantitative R&M requirements are established and prior to detailed design activity if the R&M requirements are to have any impact on the design. Different definitions should be used to define operationally relevant conditions and

to define contract chargeable conditions. The priority should be to define these two sets accurately for their two distinct purposes rather than compromising the separate accurate definitions for a single less accurate set.

CONTRACT

ELEMENT: Incentives

DEFINITION: This element addresses incentive provisions in the contract which are intended to motivate contractor actions which will result in a more reliable (or maintainable) product.

SCOPE: This element includes R&M incentives, warranty and award fee provisions that are based upon equipment performance or contractor performance with the objective of improving the reliability and/or the maintainability of the item.

QUESTIONS TO BE ADDRESSED: Which type (or combination of types) (warranty, award fee, incentive provisions) is being used? Are the incentives based upon contractor performance or product (i.e., equipment, system) performance. If product performance, what is the basis measure and measurement period? How realistic are they when compared to operational conditions? How do the R&M incentives compare to the total incentive program on the contract (relative weight, dollar amounts, time phase, etc.). Are the incentives and the basis measurement periods consistent with the program schedule?

DISCUSSION: The R&M incentive approach to a particular program should be based upon the critical R&M parameters or characteristics for that system. Once the critical parameters have been identified then the various incentive approaches must

be evaluated. Some approaches have their basis measurement only in operational service (e.g., reliability improvement warranties). Others may be applied in any time phase (e.g., award fee). The correct approach is to select the right combinations of critical parameters and incentives approaches. The R&M incentives must also be viewed in relation to the total incentive package on the contract to assure proper relative weight is given to R&M.

CONTRACT

ELEMENT: Source Selection Criteria

DEFINITION: This element addresses the question of how the source selection criteria aid in contributing to the R&M objectives.

SCOPE: This element considers both the customer's evaluation criteria stated in the RFP and the weighting or scoring method used by the source selection evaluation board (SSEB). (This latter material may be difficult to obtain and/or evaluate because of the "source selection sensitive" nature.)

QUESTIONS TO BE ADDRESSED: How was R and/or M addressed in the RFP statement of evaluation criteria? (Recognize that while the SSEB scoring may be more definitive, the RFP is visible to the contractors and has the effect of communicating the government's relative priority on the various factors.) Are there confusing or conflicting priorities between the RFP statement, relative incentive amounts, or other government statements? (One potential source of conflict may be the RFP cover letter.)

DISCUSSION: The government's priority on R&M must be reflected in both the RFP statement of evaluation criteria and in the SSEB weighting method. The first of these can motivate the contractor to propose his best design or approach to the R&M problem. The latter ensures the proper evaluation of the

alternative R&M characteristics and the potential for selecting the best approach from an R&M standpoint. Contractors will not attach high value to R&M until they see the government making selection of designs with good R&M features and rejecting ones with poor R&M potential.

CONTRACT

ELEMENT: LCC Consideration

DEFINITION: Life cycle cost consideration is the situation where the R&M requirements are developed considering life cycle cost and how it is impacted by R&M.

SCOPE: The element includes how LCC considerations impacted on the R&M design related requirements development. It also includes the impact on R&M of LCC requirements, LCC contract incentives and other contract requirements.

QUESTIONS TO BE ADDRESSED: Was life cycle cost a factor in the development of R&M design related requirements and design trade-offs? What cost factor(s) (total LCC, operations and support cost, just support cost) was used? How was it done? What specification was used? How did the requirement satisfy both LCC and mission requirements? Was LCC estimated and evaluated as the program progressed? Did this information impact R&M activities? Was there insight into the LCC implications of identified R&M shortfalls? Was LCC re-evaluated after the test and evaluation program or after production began?

DISCUSSION: One of the principle benefits of good levels of R&M is to reduce life cycle cost. Therefore LCC analysis should, either directly or indirectly, be part of the process to determine the R&M requirements. During design trade-off

studies, LCC should be addressed as one factor in evaluating alternatives. During T&E and early deployment, R&M problems might be assessed against LCC impact. LCC might also be assessed to evaluate the relative impact of system characteristics, including R&M. Payoff of this item is usually subject to skepticism due to the inherent difficulty in accurately modeling cost impact of the individual elements to the total cost (due to lack of credible and sufficient data, analytical models, consistency, etc.).

MANAGEMENT

ELEMENT: Planning, Control and Emphasis

DEFINITION: This element consists of both government and contractor management of the effort to produce a reliable and maintainable system.

SCOPE: This element will include all of the PM's management actions that are part of an R&M progam. It will specifically address R&M emphasis, planning and control.

QUESTIONS TO BE ADDRESSED: Is the emphasis placed on R&M by the government and/or contractor program manager visible and accessible? Were the PMs involved in the major R&M reviews or was it left to the R&M staffs? Were there senior management communiques or meetings on the subject of the R&M program? Were the program plans adequate, comprehensive, or perfunctory? What evidence is there that these were adhered to? Were the R&M tasks scheduled in a manner consistent with the planned design schedule? Was the schedule compressed or concurrent? How did the program actually function as compared to the schedule? What records were kept for management visibility? How did the actual conduct of R&M tasks relate to the timing of design activity? Were there any financial penalties or incentives on the timely conduct of program tasks?

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DISCUSSION: The environment that is established by senior management (government and contractor) can be critical to the success of the R&M program. This emphasis is communicated through personal involvement, written comments, and participation in major R&M and design meetings. The planning for R&M activities must be thorough but flexible. It must be consistent with the schedule of design activity so that the products of R&M activities can influence the design rather than after-the-fact documentation. Management also requires controls. There should be visibility and control procedures to assure that the R&M tasks, including those of the subcontractors, are being accomplished correctly and on-time.

ELEMENT: Monitor/Control of Subcontractors and Suppliers

DEFINITION: This element consists of management and contract methods between the prime contractor and his subcontractors and suppliers.

SCOPE: This element includes R&M contract arrangements and management emphasis on R&M between the prime contractor and his subcontractors and suppliers.

QUESTIONS TO BE ADDRESSED: Have the allocated R&M requirements been passed on? How were these tailored to the subcontractor? How did the prime contractor monitor subcontractor performance during design, analysis, etc? Was subcontractor R&M emphasis judged as adequate? How much contractor R&M activity was directed at internal design versus subcontractors or suppliers? Were any unusual methods used to communicate the priority on R&M to the subcontractors and suppliers? Were R&M incentives passed on to the subcontractor? How were the subcontractors and suppliers integrated into the other reliability tasks such as part and material control and failure analysis/corrective action?

DISCUSSION: On many systems, the R&M critical components are subcontracted. The subcontracts must reflect the R&M requirements and philosophy in the prime contract. The incentives and the

management priority placed on R&M by the government must be accurately and completely communicated to the subcontractors. The subcontractors' role in the R&M program can be critical.

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DESIGN

ELEMENT: Development of Design Requirements

DEFINITION: Development of design requirements is the process that translates program goals and thresholds to requirements for contractual specifications, statements of work, and for communication to the designers.

SCOPE: This element includes the analysis to establish the relationship between the R&M requirements and other readiness-related parameters, identify chargeable R&M requirements, develop and allocate contract R&M requirements, and translate R&M requirements for the designers in terms of design attributes.

QUESTIONS TO BE ADDRESSED: Were the program R&M goals and thresholds developed as operational measures (as opposed to contract chargeable measures)? Are they consistent with other readiness-related goals and thresholds (i.e., availability)? How were the contract R&M requirements developed? How did this process account for scenario, mission mix, wartime/peacetime, etc? Was a baseline system developed from previous systems? To what level were R&M requirements allocated? Was there an assessment of technical risk in the R&M allocation? How were R&M requirements translated to the design engineer?

DISCUSSION: The program R&M goals and thresholds should be developed based on the user's statement of his required

capability. This must be based on defined utilization, mission mix, wartime/peacetime, etc. A baseline should be defined using data on previous systems. From the goals and thresholds, chargeable R&M requirements should be developed that reduce the area of interest to those things that are chargeable to the contractor(s). There should be consistency between the R&M parameter values and other readiness-related goals, thresholds and requirements. The allocation of system requirements to lower levels allows designer and unit managers to have assigned R&M responsibilities. This allocation should identify any areas of unusual technical risk.

ELEMENT: Design Alternative Studies

DEFINITION: This element includes all of the trade studies or studies of alternatives that are accomplished prior to and in the early stages of design.

SCOPE: The scope of this element is only those studies that examine design alternatives that may result in changes in reliability and/or maintainability. These studies might include: simplification, inspectability, producibility, redundancy, useful life, LCC, BIT vs. ATE, partitioning, etc.

QUESTIONS TO BE ADDRESSED: Were design trade studies conducted aimed at improving R&M? Were other studies evaluated for impact on R&M? Was this trade study activity directed in some manner or was it open ended? How many trade studies were performed? How (or by whom) were the results evaluated? How were they documented? Were the study results acted upon? Were the studies used to identify R&M improvements or were they more correctly used to identify deficiencies or problem areas? Was the degree of freedom to change specified? If so, how and where? Did the trades result in identifiable cost savings to the contractor?

DISCUSSION: The aggressive conduct and acceptance of alternative design trade studies can have a significant impact in establishing

the design (and R&M of the design) baseline. If the trade study program is aggressively managed, it will be directed at finding a proper balance between the many demands on the system design. This balance should attach enough importance to readiness and support considerations and risk that alternatives also examine improving R&M to the detriment of other system characteristics. While trade studies may uncover design deficiencies, the thrust of the program should be directed at developing improvements in the baseline design. Trades may also result in changing support concepts or deployment to reduce the support tail, but this study is directed toward the equipment design aspects.

DESIGN

ELEMENT: Design Evaluation Analysis

DEFINITION: This element is the analyses that evaluate the design and provide a basis for iterative design influence, correction or improvement from an R&M standpoint.

SCOPE: This element includes thermal (and other environmental) analysis, electrical (and other) stress analysis, worst case tolerance analysis, sneak circuit analysis and other detailed analyses that should be done as the detailed design is done on an iterative basis, numerical predictions, failure modes, effects and criticality analysis, thermal survey, and maintainability analysis.

QUESTIONS TO BE ADDRESSED: Were these analyses integral parts of the design process? Who performed these analyses? Were they contractually required or a contractor initiative? Did the results of these analyses have an impact on the design? What evidence is there of this? How did management view these tasks (i.e., work to be done, or inputs to design or merely contractual deliverables)? As the detailed design was changed during the development program, were the R&M design analyses updated to evaluate the design changes? If allowed, would the contractor reduce these requirements?

DISCUSSION: The design evaluation analyses are best done by designers as an integral part of the detailed design. The results of these analyses must provide information to designers and engineering managers so the analyses are actually causing change in the design rather than just recording the design that exists. The timing and the credibility of these analyses must be such that they are accepted as part of the design evolution. A common flaw in many R&M programs is to have the R&M analyses separated from design activity by time (in this situation the analysis merely documents the characteristics of the design without affecting the design chosen), distance or organization. Separation by organization can have positive or negative impact depending upon the organizational factors (and personalities) involved. These situations require evaluation that may be difficult in a short period of time. The role of R&M analyses in design changes can often be an indicator of the importance placed upon these tasks by the design team.

DESIGN

ELEMENT: Parts and Material Selection and Control

DEFINITION: This element includes the procedure, process and controls used by the government and the contractor to assure that the parts and materials used to manufacture the item are proper for the required level of R&M.

SCOPE: This element addresses both parts and material selection It includes environmental stress screening requirements imposed at the part vendor's facility.

QUESTIONS TO BE ADDRESSED: Did the program follow the parts control process in MIL-STD-965 (or its predecessor documents)? Was there a parts control board and/or an approved parts list? Were electronic parts restricted to the "high reliability" specifications (ER, TX, TXV, 38510, etc.)? Who could grant an exception to this rule? Was there source control of standard and non-standard parts? What numerical percent of the electronic parts were from the approved "high reliability" specifications? How were materials controlled? Was there a board to control the material selection? Were the parts and material control procedures contractual? What control was exercised by the government? Did this element have an identifiable cost (in dollars and/or man-hours)? Were there identifiable benefits to the contractor above meeting contractual requirements (i.e., did assembly test reject rate improve)?

112/16-1

DISCUSSION: A well defined, properly executed parts (and material) selection program can reduce one source of potential reliability problems. Restricting appropriate classes of parts to well-understood, high volume components with increased assurance of part quality, can contribute significantly to producing a reliable product. The control procedures should be well-defined. Part screening requirements should be established and enforced. The approved parts list should be available before the designer is ready to select components. The authority for granting exceptions to the control procedure should be well-defined and monitored to assure that exceptions are not granted too freely. This element must have a close interaction with the environmental stress screening of parts, assemblies, etc.

ELEMENT: Derating Criteria

DEFINITION: This element addresses the establishment of criteria for acceptable derating and the enforcement of that criteria.

SCOPE: The element addresses derating of component parts and materials.

QUESTIONS TO BE ANSWERED: Was there an established derating criteria? Who established it? Who could approve deviations? What magnitude of deviations were approved? Were these significant in the context of the total design? How did the criteria compare with other existing standards (e.g., NAVSEA, NAVMAT, RADC TR)? How did the resulting design compare with the derating criteria? Were measurements taken of actual stress levels? What were the highest stress level parts and what technical requirements (e.g., weight, size) impacted the derating levels? Did failure data indicate that the criteria was acceptable and complied with? Are thermal evaluations made in the field and empirical data gathered, if required, and compared to predicted derating?

DISCUSSION: Almost all programs have derating criteria. The principal problem has been enforcement or the granting of deviations. Derating criteria should be established consistent

with one of the published guidelines. Careful enforcement should assure that unnecessary deviations are not granted.

ELEMENT: Thermal-Packaging Criteria

DEFINITION: This element consists of the design criteria and guidelines that are established to guide designers to provide a design that has proper thermal and packaging characteristics.

SCOPE: This criteria addresses the thermal and packaging characteristics of equipment (primarily electronics although other sensitive items should be included) and other environmental characteristics that might be critical to the design, e.g., vibration.

QUESTIONS TO BE ADDRESSED: Was a criteria established for the thermal design? Was this criteria influenced by the contract? Was it consistent with the derating criteria? Was implementation of the criteria monitored by the design reviews? Were there tests performed to verify the implementation of the criteria and to determine the actual pay-off in equipment characteristics (junction temperatures)? How was the packaging criteria addressed?

DISCUSSION: The approach and criteria of thermal and packaging design can be critical to the success of the design. The criteria might address the thermal paths to be used (e.g., direct cooling, cold walls, flow through cold plate cooling).

Discussion of these methods is in the RADC "Thermal Guide for Reliability Engineers." This document provides a good review of this subject area.

DESIGN

ELEMENT: Computer Aided Design

DEFINITION: This element consists of computer aided engineering tools to help design a reliable and maintainable product.

SCOPE: This element includes computer assisted analysis that aids in assessing the R&M of the design or optimizing the R&M of the design. This includes computer-aided circuit development, thermal and/or vibration analysis, R or M prediction, circuit board layout, test point selection, test and troubleshooting programming and partitioning.

QUESTIONS TO BE ADDRESSED: Were computer aided R&M tools used? Which ones? How did these analysis tools and their products interrelate with the main detailed design process? Did these tools make it easier to create a reliable design and reduce the introduction of design flaws that could have resulted in lower R&M? Were the computer tools linked together? Were there other computer-aided-design tools used? Did these tools optimize the design on a basis contrary to R&M? What are the estimated costs vs. benefits compared to a non-CAD?

DISCUSSION: Computer aided design (CAD) is the use of computer-assistance to help the designer produce a design that satisfies a number of design constraints and optimizes other design

features. Computer analyses are tools that in an automated manner attempt to optimize a characteristic of the design, or other automated analyses. CAD for R&M can consist of R&M predictions that the designer can evaluate, the identification of overstressing, sneak paths, malfunction choke points as well as automated decision making that forces the design alternatives to meet certain constraints. Key to evaluating CAD is to examine the priority of R&M in the CAD process as compared to technical performance, weight, etc. and whether viable, cost effective recommendations resulted from the process. Does the CAD process make the design of a reliable, maintainable product harder or easier?

DESIGN

ELEMENT: Testability Analysis

DEFINITION: This element is the design analysis effort related to developing the diagnostic approach and implementing that approach.

SCOPE: This element includes BIT analyses, nodal analysis for partitioning, test point design, fault simulation, and diagnostic preparation for all specified levels of maintenance.

QUESTIONS TO BE ADDRESSED: What was the process whereby the contractor defined his testability (Built-In-Test) design approach? Was the testability design concurrent with or after the major equipment design? Did test point selection and design and testability partitioning play a major role in the system layout and packaging? Was a failure modes and effects analysis available and used as part of the testability analysis? Were BIT analyses and fault simulation used to evaluate the coverage and effectiveness of the BIT design? Was the testability design approach evolved as information was obtained from analyses and test experience? How did the results compare with the requirements?

DISCUSSION: Testability analysis should be used to define diagnostic requirements before the detailed design. During the

detailed design, test point analysis and nodal analysis for partitioning should be major inputs to the layout/packaging design. Analyses of projected BIT performance and fault simulation studies should be used to evaluate the progress toward the BIT objectives and as inputs to a BIT maturation program. Design improvement data should also be extracted from other test and operational data.

ELEMENT: BIT and ATE Performance

DEFINITION: This element is the task associated with BIT/ATE requirements development and BIT/ATE evaluation and assessment.

SCOPE: This element includes establishment of the requirements for the diagnostics, the specification of these requirements, the assessment of BIT/ATE performance, and the maturation of diagnostic systems.

QUESTIONS TO BE ADDRESSED: What are the BIT requirements? How were they derived? What is the relationship between the BIT requirements and the ATE? Is information from the BIT available to and used by the ATE? How was the progress of the BIT design monitored and evaluated? What method was used to demonstrate, contractually, the BIT performance? How valid was this prediction? Were any unique tools or methods used to design, develop or mature the BIT system? How was the BIT system assessed in early operation? What was level of false alarms, could not duplicates, retest-OKs? Were there BIT/ATE compatibility problems?

DISCUSSION: The procedure to define the required BIT performance has not been developed to any proven level. Regardless of the requirements, the analytical assessment of BIT levels should

have adequate attention to assure that problems are corrected when first identified. Similarly there must be attention to early test and early operation experience with BIT. BIT/ATE compatibility must also be assured.

DESIGN

ELEMENT: Features to Facilitate Maintenance

DEFINITION: This element addresses maintenance requirements and their inclusion into design constraints directly as well as influencing R&M requirements. The premise is that maintenance requirements must be supported by system design.

SCOPE: This element includes consideration of physical attributes, diagnostic, simplification, repairability, testability, inspectability, accessibility, supportability and maintenance time/cost design criteria commensurate with the maintenance profile of the system.

QUESTIONS TO BE ADDRESSED: What was the methodology used in developing the maintenance concept? Was the maintenance concept systematically reviewed? How was it specified? Is the system design compatible with the maintenance resource development? Is the system design "friendly to maintenance" in providing accessibility, fault isolation capability and packaging for repairability? Are calibration and precision measurements readily accommodated? Is the system packaged for fault isolation and repairability as required by the maintenance concept, manpower and skill restraints? Can sub-units be successfully maintained at their designated repair levels as functional entities? Are design trade-offs considered with respect to maintenance requirements? Are trade-offs documented, reviewed

and complied with? Is there on-going maintenance systems engineering involvement in system design?

DISCUSSION: Qualitative and quantitative maintenance requirements must be established to provide system design guidelines especially during system development. Prior to detailed design, a system maintenance concept should be formulated. Maintenance requirements identification is a key contributor to cost effectiveness. When Life Cycle Cost is minimized, a major factor is optimum maintenance. Improved maintenance enhances system availability, therefore increases user operational readiness. The ability of maintenance to improve operational readiness is a function of R&M. Maintenance systems engineering develops concepts, criteria and technical requirements to assure timely, adequate and cost effective support of system design and operational needs.

MANUFACTURING

ELEMENT: Environmental Stress Screening of Parts/Equipment

DEFINITION: This element addresses the environmental stress screening (ESS) of parts, assemblies, and systems during manufacturing.

SCOPE: This element includes part (or component) screening as part of receiving inspection, screening (or non operating "conditioning") of assemblies, and the screening of "black boxes", subsystems and systems.

QUESTIONS TO BE ADDRESSED: Has an integrated stress screening program been established? How were the requirements established? To what extent is the contractor doing screening to incoming electronic parts (by part classes, type of screens, 100% or sampling)? What cost or cost/benefit data is available? What does reject data indicate? What is done at the assembly or printed circuit board level? What is screened at subsystem or system level? What is distribution of failures at these levels (design/parts/workmanship)? Is there a failure-free period required? What level of contractor or government controls the ESS requirements? Have there been changes or revisions? What costs are available (equipment, manhours, etc.)? How many thermal cycles and what was the range and rate of change. How has this been documented? To what degree are subcontractors required to accomplish the above?

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DISCUSSION: The 1981 guidance pamphlet published by the Institute for Environmental Sciences (IES) is a good baseline for the development of a comprehensive ESS program. The use of ESS as part of receiving inspection can be economically justified for some part types. Engineering judgment must be made as to which specific screens will be most effective. The receiving screens supplement or replace the screening programs that are normally applied at the part manufacturers. With the limited historical experience, it is important for screening programs to remain flexible. Control of screening details should allow for adjustments as production is performed, with government control of some final result (system level burn-in with a failure free period might be such a criteria).

MANUFACTURING

ELEMENT: Failure Reporting, Analysis and Corrective Action System (FRACAS)

DEFINITION: This element is a closed-loop activity which provides visibility of potential and observed problems, the failure analysis performed, and the corrective action taken for resolution. It is applied throughout the life cycle of the product to individual problems and problems in aggregate. (Factory defects from production inspection and test are accounted for by the Quality Program).

SCOPE: Two classes of problems exist and are included in the corrective action systems. The first, potential problems, are those revealed as a result of design review activities or failure modes and effects analysis. The second, observed failures, are failures observed during the various phases of the manufacturing process.

QUESTION TO BE ADDRESSED: Is there appropriate management support to allow the loop to close effectively? Has the system been designed to collect information sufficiently, accurately and in a timely manner? How were failure analyses accomplished? What techniques were used? Has the definition of "closure" been agreed to and precisely defined in the R Program Plan? What management reporting, evaluation and controls were implemented to effect problem closure as well as to measure the effectiveness of the FRACAS?

RECOMMENDATIONS: Problems or failures manifest themselves in a variety of ways. These include catastrophic failures and out of tolerance drift. Causes vary from operator error, overstress, handling damage, spontaneous failure of piece parts, aging, degradation, etc. Appropriate effort is required for recognition, diagnosis and correction at the earliest possible phase in a product's life cycle. Cost in dollars and delays increase by orders of magnitude if the defect is allowed to manifest itself at higher levels of assembly or later in the life cycle. Potential problem identification and resolution is the most productive effort because the design can be changed more easily before it is released for production. Real problem identification and correction have very tangible benefits/cost visibility.

TEST AND EVALUATION

ELEMENT: Design Limit Qualification Test

DEFINITION: Design limit qualification testing consists of tests to qualify the design to the limits specified in the contract, specification, etc. These tests demonstrate that the design can perform satisfactorily at the design limits. There is usually only minimal operating time required at each limit.

SCOPE: These design limit or qualification tests are usually drawn from military standards (e.g., MIL-STD-810) and address environments (e.g., temperature, altitude, vibration, salt, fog, etc.), compatibility (electro-magnetic interference), endurance, and other factors.

QUESTIONS TO BE ADDRESSED: These tests are thought of by some persons as performance tests, therefore what was the priority on these tests versus tests in R&M? What was the sequence of these tests? How did they relate schedule-wise to the reliability and maintainability tests? Was R or M data collected from these tests? Were there reruns of sections of the tests? Were there R&M related design changes addressed that were incorporated after these tests? What process determined the design limits (military standard, mission profile, etc.)? Were failures from these tests reported under the failure analysis/corrective action program? Are costs and returns on investment identifiable?

DISCUSSION: This test phase is sometimes not thought of as an R&M element. The tests examine the capability of the design (normally one sample) to meet the performance requirements at the design limit (normally for a short period of time or for a short performance test). There is usually no attempt to gain "hours" to assess quantitative reliability. The interrelationship between these tests and R&M tests can be critical to assure that the final design is adequately tested. The failure data (and diagnostic data) from these tests can be valuable since it will be some of the earliest data available. Design changes made later in the cycle (after reliability growth test?) should be evaluated as to their impact on the results of the design limit tests.

TEST AND EVALUATION

ELEMENT: Reliability Growth Testing

DEFINITION: Reliability growth testing is a planned, pre-qualification, test-analyze-and-fix process in which equipments are tested under actual, simulated, or accelerated environments to disclose design deficiencies and defects.

SCOPE: This element includes the actual growth testing, the analysis, redesign, and retesting.

QUESTIONS TO BE ADDRESSED: Was a reliability growth program required by contract, or self imposed? What was the test length (i.e., hours) and how was this determined? What was the test environment and how was this determined? Was there a reliability growth prediction? Did the results track the prediction? Were all failures analyzed? How? Were corrective actions taken on all failures? How many units were used for growth testing? Was some of the reliability growth the result of "burn in" of the test units? What was the cost of the total RGT (test units, hours, analysis, corrective actions)? How did the RGT relate to the rest of the design cycle? When was it completed and all redesign done? Were there outstanding deficiencies? How did it relate to reliability qualification or demonstration testing?

DISCUSSION: Reliability growth testing can be a very effective task in the development of reliable complex equipment. The need for this task depends on the reliability risk that is projected to remain in the design after the reliability design tasks. The test plan, environments, number of test units, equipment operating sequence, procedures for failure analysis and corrective action, time phasing with the rest of the development program are all critical to the success of the growth test. Management's interest in the progress of the growth test can be a positive factor in keeping the growth test on schedule.

ELEMENT: Demonstration Testing

DEFINITION: This element addresses the physical display of acceptable reliability or maintainability levels.

SCOPE: Demonstration testing is used in both DT&E and OT&E. Typical demonstrations include laboratory (stress screening, CERT, etc.) and operational (maintainability demonstration, qualification testing, etc.) displays of the system's capability to meet some stated requirement.

QUESTION TO BE ADDRESSED: Were demonstrations required in the contract? What criteria was used for demonstrations? How and by whom were these specified? What techniques, specifications and conditions were used? Were demonstrations used as the sole measure of acceptance? If so, did they provide adequate information for decisions? How was data from demonstrations used? Did demonstration effect design concepts?

DISCUSSION: To some degree demonstrations are useful, but they generally are not adequate stand alone measures of system performance. Used in conjunction with other R&M development techniques, demonstrations have more potential to impact system

design. In the area of operational testing, demonstration data can be useful if applied properly.

TEST AND EVALUATION

ELEMENT: Operational Test and Evaluation

DEFINITION: This element addresses the assessment of a weapon system under the use, maintenance and environmental conditions for which it was designed to be employed.

SCOPE: Operational testing is the means by which weapon system performance and supportability characteristics are evaluated. Weapon system operational effectiveness (performance) and operational suitability (logistics supportability, i.e., reliability, maintainability, availability, support costs, etc.) critical issues are addressed during test and evaluation to determine the weapon system's capability to accomplish its assigned mission.

QUESTIONS TO BE ADDRESSED: What were the critical issues defined in the test plan? Did the critical issues reflect using and supporting command concerns? Were adequate test assets available? Were support resources (technical data, support equipment, diagnostics, spare parts) available and used during the test? Were weapon system deficiencies discovered during test corrected and verified? Did information derived from the test influence design change or support concept change decisions? Were thresholds and goals well established by the user, if not how were test criteria determined? Was there adequate feedback to the program office, contractor and subcontractors?

DISCUSSION: Operational testing should be used to aid developers in fine tuning a system to fulfill the user's needs. Those areas where test and evaluation was used as a means to improve system performance and support must be identified to illustrate the benefits of operational testing. Where test and evaluation had no effect on improving the system the reason should be identified.

TEST AND EVALUATION

ELEMENT: In-Service Assessment

DEFINITION: This element addresses efforts to analyze R&M problem areas and develop corrective actions for systems in early operational use.

SCOPE: This element includes analysis activity, data collection, engineering review activity, and implementation of corrective actions to identify and correct field R&M problems.

QUESTIONS TO BE ADDRESSED: Was there a plan (with identified engineering support, data collection and analysis, etc.) to identify and correct R&M problems during early operational service? What data system(s) were used? What was involvement of prime contractor, subcontractors, user personnel, test activity? How long was the assessment period? Was the system used in its intended manner? How did R&M of system change during this period? What was the cost of this assessment program? Was it adequately funded? If not, what were the shortfalls in cost, schedule and tests?

DISCUSSION: Once a system is introduced into the operational environment, the environment (including personnel) and full production rate can introduce a new set of R&M problems that must be identified, analyzed, and corrected. This

normally requires planning, assignment of engineering resources, selection of an R&M data system, etc.

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